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UNIVERSAL DESIGN EVALUATION APPLIED ON STATION SIGN SYSTEM INNOVATION DESIGN

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Abstract

Transportation facilities are used by numerous people from a broad range of groups. Therefore, to fulfill the principles of universal design (UD), transportation environments must be designed with maximum ease of use for all people in mind, which will enable sustainable social development to be achieved. This study focused on improving upon the flaws in the sign system for the main passageways in Banqiao Station in New Taipei City, Taiwan. A new sign system was designed for the transfer route from Taiwan Railways to the Mass Rapid Transit system, and a three-dimensional virtual reality scenario was incorporated for a UD evaluation test to reinforce the UD procedure. The flaws in the existing sign system were divided into six groups: (1) missing information; (2) interference with vision and sight; (3) unintegrated sign design; (4) unintegrated sign information; (5) disturbance from environmental lighting; and (6) unclear directional positioning. The types and locations of the signs were redesigned, and the visual design and information contents of the sign system were integrated systematically, after which the setup planning and design improvement of the sign system was implemented according to the flaws identified by users. According to the test results of the users, the existing sign system does not fulfill the principles of UD, particularly in terms of its flexibility, safety, and aesthetics. The new sign system satisfies the requirements for UD; in particular, significant improvements in informativeness and safety were noted.

Keywords: Universal Design Evaluation, Sign System, Innovation Design, Transportation Environment

Introduction

Universal design (UD) is a human-centered type of product and environment design that is suitable for all people regardless of age, gender, and diversity to the maximum possible extent (Story et al., 1998; Clarkson & Coleman, 2015). Transportation environments, which are used by numerous people from a broad range of population groups, should be designed for all people to access with the greatest ease possible, thereby facilitating sustainable social development (Sue Morgan & Environment, 2017). UD was first proposed by Ronald L. Mace, the late director of the Center for Accessible Housing (now the Center for Universal Design) at North Carolina State University (Story et al., 1998; John Clarkson & Coleman, 2015). UD, which is promoted worldwide today, refers to a type of product and environmental design that is suitable for all people regardless of gender, age, and capabilities to the maximum extent possible.

Studies and practices of UD have been conducted to maximize the accessibility of transportation systems for users, not just for gender, aging, impairment, and wheelchair users, but also for different kinds of pedestrians. Accessibility is improved through additional efforts to compensate for flaws in the basic design of an area or product. Accessibility is highly associated with legal requirements, and existing regulations can no longer satisfy the increasingly diverse needs of passengers.

In addition, improving upon flaws that are overlooked in individual transportation facilities can be considered as universal design, exceptionally designed facilities that are inaccessible because of inappropriate configurations and functions are also found in real transportation environments. Practically, the holistic UD perspective should not be overlooked; it involves holistically analyzing the design elements of a facility and the user behaviors involved in various transportation systems. Future transportation environment designs must fulfill increasingly diverse usage and interaction behaviors; therefore, governments must design such environments to fulfill the needs of all passengers with various capabilities and requirements.

The goal of this study was to demonstrate the feasibility of UD through a presentation of examples in sign system design to ensure the gradual promotion and implementation of UD in future transportation environments. The main objectives of this study were as follows: (1) To clarify the problems and needs in the use of an existing sign system and propose corresponding improvement plans. (2) To evaluate whether the existing sign system and a newly planned one satisfy UD principles. (3) To compare the existing and new sign systems in terms of their differences and effectiveness. (4) To provide suggestions and guidelines for improving future sign system design.

Scope of the Research

Banqiao Station, located in New Taipei City, Taiwan, is a station shared by the Taiwan Railways Administration (TRA), High Speed Rail (HSR), and Mass Rapid Transit (MRT) systems and features bus and transfer stations at its east and west exits. As a major transportation hub, it must integrate various facilities such as ticketing systems for different types of vehicles, elevators and escalators, and signs. Finding paths to the different lines is particularly difficult because of the long distances between them; therefore, the station serves as a suitable site for observing the effectiveness of UD improvement in the sign system. Accordingly, this study focused on improving the sign system for the main transfer lines in Banqiao Station. This study focused on the transfer route to the MRT line in Banqiao Station.

Research Procedure

This study consisted of four steps.

(1) Investigating the problems and needs: The information content required in the sign system and other relevant facilities were clarified according to their installation purposes. In addition, the path conditions of the signs' preset locations and surrounding areas were examined, as were their installation statuses, colors, shapes, sizes, and means of information provision.

(2) Analyzing the problems: The problems collected in the previous step were analyzed and the installation locations, methods, and facilities for the signs were specified. The information to be embedded in the signs was clarified and the information to be provided was rigorously selected in consideration of the signs' limitations. The configuration of the information content was planned, thereby providing a reference for future plans to further improve the sign system and other related facilities.

(3) Improving the design of the sign system: The basic design of a sign comprises its size and the configuration of its structure and information content. On the basis of the approximate configurations of the signs, this study reviewed and modified the facilities, installation locations and methods, information content, and configurations of the signs as necessary from the perspective of UD, particularly regarding their accessibility and sharing. Subsequently, this study ensured that the signs' UD, installation locations, information contents, and display methods could fulfill the needs of as many users as possible. When necessary, special signs were implemented for special groups in the sign system design.

(4) Running a 3D virtual reality (VR) simulation test: This study used VR technology to simulate a real transportation environment and ran a comprehensive UD evaluation on the existing and new sign systems to confirm whether the new one met the expectations of users and the improved design

Figure 1. The research area of this study in Banqiao Station.

had been effective. The goal of this study was to provide examples of design planning for systematic sign systems.

Wayfinding

Wayfinding refers to an individual's observation and understanding of an urban environment, and it explains the general intellectual performance of people under external influences when finding paths. Perceptual memories combine an individual's past experience with the description and guidance conveyed in the instructions encountered concurrently (Lynch, 1960). As the types of spaces have changed and increased over time, relationships between spaces have been affected and garnered increasing attention. Because people have increasingly emphasized spatial activities, scholars have researched wayfinding by redefining it and expanding its scope of application, such as wayfinding behaviors, spatial cognition and orientation, and cognitive maps. Passini contended that spatial orientation perception is the most critical factor in spatial concept building (Arthur & Passini, 1992). As technology has evolved over time, VR has been employed in research on wayfinding since 1993 (Cruz-Neira et al., 1993). Fewings proposed eight effective spatial concepts to assist in wayfinding and terminal design (Fewings, 2001): (1) use a visual indicator system to maintain the use of space; (2) use any possible environmental and internal configurations; (3) place signs at decision points; (4) design signs for users of different age groups; (5) establish signs that are easy to read, direct, and prominent at appropriate distances; (6) ensure consistency in the graphic design and placement of signs in the entire space; (7) label only the most critical information to prevent visual confusion; and (8) integrate visual guidance with design concepts. These concepts were incorporated into the present study to establish sign setting regulations that can be followed for improving the sign system in Banqiao Station.

Table 1. Universal design principles and indicators.

	Seven principles of North Carolina State University, USA	Seven principles and three supplementary principles of Satoshi Nakagawa	UD principles adopted for transportation in the present study
Principle 1	Equitable Use	Equitable use	Equity and Reassurance
Principle 2	Flexibility in Use	Flexible use	Flexibility
Principle 3	Simple and Intuitive Use	Simple and intuitive use	Operability
Principle 4	Perceptible Information	Perceptible key information	Informativeness
Principle 5	Tolerance for Error	Error-tolerant design	Error tolerance and Safety
Principle 6	Low Physical Effort	Low physical effort	Labor efficiency
Principle 7	Size and Space for Approach and Use	Reasonable size and space	Reasonable planning
Supplementary principle 1		Durability and economy	Durability and Economy
Supplementary principle 2		Quality and aesthetics	Comfortability and Aesthetics
Supplementary principle 3		Health and environmental friendliness	Environmental friendliness and energy efficiency
Other			Discoverability Maintenance status

UD Specifications for the Sign System

This subsection discusses the sign design guidelines commonly adopted by experts from industry, government, and academia, which were used as the basis for proposing specifications for information signs and guidelines and suggestions for visual signs.

For equitable use, multilingual design should be adopted to ensure foreigners clearly understand the information content of signs. In Japan, Japanese and English signs are generally adopted (Chishaki & Kajita, 2004), and those in international transfer stations are displayed in multiple additional languages such as Chinese and Korean (*Transport and Environment in Japan*, 2019). In Finland, Finnish, English. Chinese and Japanese are adopted in the sign system (Schweiger et al., 2006) (Story et al., 1998; Nakagawa, 2006; Afacan & Erbug, 2009; Sakai city, 2019), whereas Taiwan incorporates Chinese and English into its sign system (Symbol Design: Guidelines for Designing Common Symbols for Public, 2003) . These measures are intended to enable foreigners who are unfamiliar with the local language to understand signs clearly.

Specifications are formulated for the images, texts, and colors of signs to enable them to display easy-to-understand information. According to the guidelines by The Foundation for Promoting Personal Mobility and Ecological Transportation, Japan(Transport and Environment in Japan, 2019) and report for Universal Design by the TRA(Architecture and Building Research Institute, 2015) , effective text sizes can be identified at different sight. According to the current planning in Banqiao Station, the maximum distance between each pair of overhead light boxes is 23 meters. Furthermore, the heights of large Chinese and English text are 95 and 60 millimeters, respectively, fulfilling the specified effective text sizes; the heights of small Chinese and English text, which serve as auxiliary texts for the symbols, are 65 and 50 mm, respectively. The recognition range of the texts is 15 meters from the light box. Gothic fonts are adopted in the texts for easy recognition (Transport and Environment in Japan, 2019) .

In Japan, Europe , and Taiwan, symbol explanations are incorporated into signs to enable users who cannot understand text signs to clearly determine the directions to follow (Rickert & Others, 2006; Symbol Design: Guidelines for Designing Common Symbols for Public, 2003; Transport and Environment in Japan, 2019; Tanaka & Iwata, 1999) . In the routes and ticket prices for rides and transfers, combinations of colors, patterns, lines, and texts are incorporated for people who cannot understand any language to promptly identify the required information (Incorporated et al., 1996; Rickert & Others, 2006). Continuity combinations with walls and floors as well as color contrasts with environments are incorporated to deliver path information to passengers (Tanaka & Iwata, 1999).

In consideration of the characteristics of visually impaired users, seniors with cataracts and declining vision, and color-blind users, colors with brightness contrasts of 5 or higher must be applied in images, texts, and symbols on signs to highlight the information content for improved readability and memorization (Tanaka, 2009; Transport and Environment in Japan, 2019). To assist users with colors and lines, the characteristics of the signs' background colors should be understood thoroughly, and their contrast and balance should be considered, in order to guide passengers to the correct directions.

To mitigate sign systems' physical burden on users, spatial partition arrangement is adopted for signs in Europe to enhance their readability, and the case characteristics of European texts are coordinated with text sizes for appropriate arrangement, strengthening their readability and visual harmony (Schweiger et al., 2006). Moreover, overhead signs are integrated or separated according to their categories and the directions they indicate to reduce reading difficulty (Tanaka, 2009; Tanaka & Iwata, 1999).

For quality and aesthetics, the sign system in Japan incorporates walls as media for guidance within stations (NPO. FUKUOKA Design League, n.d.); the designs of these media are interwoven with local historical street images and colors to achieve aesthetic appeal in addition to travel information delivery. The design of station signs in Japan, which integrates cultural images, is unique and highly aesthetic.

Accordingly, user groups and their wayfinding needs have been factored into visual signs in transportation facilities in Taiwan. Combinations of texts, images, and colors are incorporated to improve the recognizability of the signs for navigation, path labeling, warnings, and facility locations, enabling users to interpret sign information promptly. For enhanced visual harmony, a holistic environmental integration involving the architectural space (e.g. floors, walls, columns, and ceilings), environmental colors, and spatial forms can be adopted.

Materials and Methods

Participants

UD must satisfy the needs of various users to a maximum extent; hence users' participation in evaluation is valued (Ministry of Health and Welfare, 2015; Japan Human Factors and Ergonomics Society, 2003; Transport and Environment in Japan, 2019). The participants of this study were divided as follows: (1) general, (2) elderly, (3) manual wheelchair users, (4) electric wheelchair users, (5) hearing impairments, (6) fully visually impairments, (7) users with weak vision, (8) color-blind or -weak users, (9) pregnant women, (10) infant carriage users, (11) users carrying heavy objects, (12) foreigners, (13) facility managers, and (14) experts.

The pedestrians' opinions were systematically incorporated in improvement designs and plans to provide accurate UD evaluations and a reference for facility improvement (Sakai city, 2019; Sawada et al., 2012). All users with partial visual impairment were capable of independent movement. To prevent the participants' learning behaviors in wayfinding from affecting the survey results, with the exclusion of the experts, different groups of users were surveyed regarding the existing and new sign systems and the guidance app.

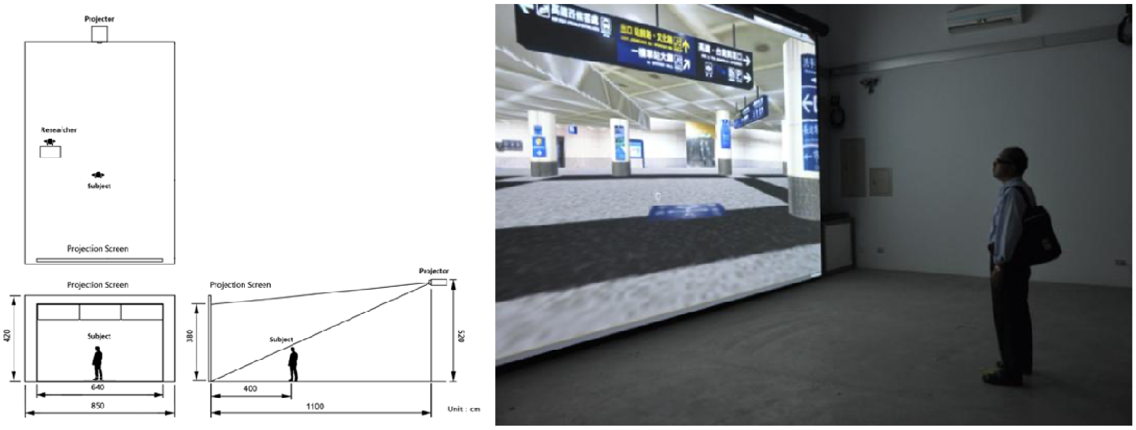
Apparatus

The test was conducted in the studio room of Tatung University. A proportional 3D model was established using the floor plan of the first basement floor of Banqiao Station in conjunction with the actual spatial size of the basement. Photographs of the actual scenarios in the station were captured and attached to the model to complete the virtual scenarios of the existing and new sign systems. A video camera emulating a user's perspective was established using a software program and projected on a screen through a projector to simulate the perspective of a pedestrian searching for a destination in the station. The height range of the projector was set as 380 cm, the installation height of the existing signs, to reproduce the guidance signs and people's actual visual perception of the overall space.

Table 2. Demographic information of the evaluators.

Variable		Sign System (1) Count	(1) % of Total	(2) Count	(2) % of Total	(3) Count	(3) % of Total	Total Count	Total % of Total
Gender	Female	22	23.2%	15	15.8%	5	5.3%	42	44.2%
	Male	17	17.9%	19	20.0%	17	17.9%	53	55.8%
	Total	39	41.1%	34	35.8%	22	23.2%	95	100.0%
User	General	4	4.2%	4	4.2%	4	4.2%	12	12.6%
	Elderly	2	2.1%	3	3.2%	2	2.1%	7	7.4%
	Manual wheelchair	3	3.2%	3	3.2%	3	3.2%	9	9.5%
	Electric wheelchair	2	2.1%	4	4.2%	0	0.0%	6	6.3%
	Hearing impairment	3	3.2%	3	3.2%	4	4.2%	10	10.5%
	Weak vision	6	6.3%	3	3.2%	0	0.0%	9	9.5%
	Color Blindness	2	2.1%	2	2.1%	0	0.0%	4	4.2%
	Pregnant women	3	3.2%	3	3.2%	1	1.1%	7	7.4%
	Infant carriage users	3	3.2%	4	4.2%	3	3.2%	10	10.5%
	Heavy objects	4	4.2%	3	3.2%	3	3.2%	10	10.5%
	Foreigners	3	3.2%	2	2.1%	0	0.0%	5	5.3%
	Facility managers	1	1.1%	0	0.0%	1	1.1%	2	2.1%
	Experts	3	3.2%	0	0.0%	1	1.1%	4	4.2%
	Total	39	41.1%	34	35.8%	22	23.2%	95	100.0%

(1) = Exist Sign System, (2) = New Sign System, (3) = New Sign System with Navigation App



(a)

(b)

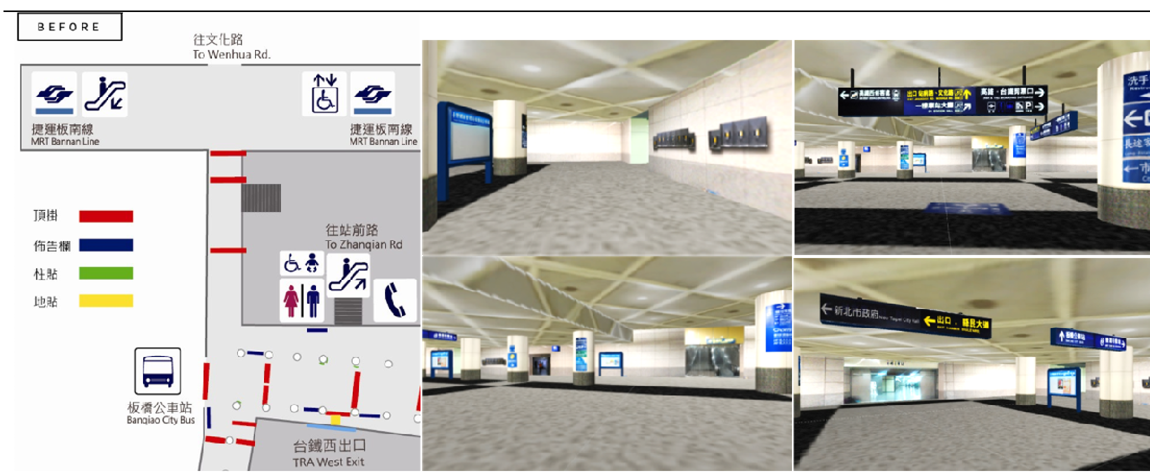
Figure 2. Configuration of test environment: (a) existing sign system and (b) new sign System

Development of Sign System

The following problems related to the existing signs and guidance information along the route from the west exit of the station to the MRT Bannan Line were collected and examined: (1) missing information, (2) disturbance to vision and lines of sight, (3) inconsistency in sign design, (4) lack of integration in sign information, (5) disturbance from environmental lighting, and (6) unclear orientation. According to the problem investigation results, the following five principles were established for the installation of signs: (1) removing the facilities that block pedestrians' paths and signs with unintegrated information; (2) moving the lightboxes that are excessively close to the exits to the central passageway for improved recognizability; (3) placing wall posts depicting maps of the relative locations of station facilities at the exits to indicate the directions to the main facilities; (4) providing wall lightboxes that depict station floor plans and guide maps at the exits; and (5) placing column maps labeling users' current locations and depicting passageway and facility floor plans at the major intersections. The new sign system adopts fives types of signs: overhead lightboxes, column posts, wall lightboxes, wall posts, and location indicators. QR codes are attached to the wall lightboxes and column posts to provide information related to the destinations and enable users to determine the routes using the in-station navigation app.

Table 3. Types of problems in the sign system and specific details.

	Discoverability	Equity	Flexibility	Operability	Informativeness	Error Tolerance and Safety	Labor Efficiency	Reassurance	Reasonable Planning	Maintenance Status	Comfortability	Aesthetics	Durability	Economy	Environmental Friendliness
Main Problems	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Missing information	v	v		v	v			v							
Disturbance to vision and lines of sight	v				v	v									
Inconsistency in sign design		v	v	v	v	v	v	v	v		v	v	v		v
Lack of integration in sign information	v				v		v					v			
Disturbance from environmental lighting			v		v										
Unclear orientation		v		v	v	v	v	v	v						



(a)

(b)

Figure 3. Comparison of the (a) existing sign system and (b) new sign system in the VR scenario.

Experimental Setup

In the present study, the tasks were set as passengers' procedures in operating the facilities for holistic evaluation (Misugi et al., 2003; Kumiko et al., 2006; Nakagawa, 2006; Sakai city, 2019). Before the test began, the participants were asked to fill in the demographic information and read the contents and evaluation items in the questionnaire; any unclear information was explained in advance to enable the participants to immediately understand and answer the questionnaire contents. During the test, the participants were arranged in designated locations. The researchers coordinated the participants' movement instructions in operating the movements on the screen and objectively recorded the participants' statuses and reactions during wayfinding. Participants for whom this task would be inconvenient were assisted in filling out the information and answering the questionnaire. For example, users with hearing impairment were provided with sign language assistance and foreigners were provided with translation assistance.

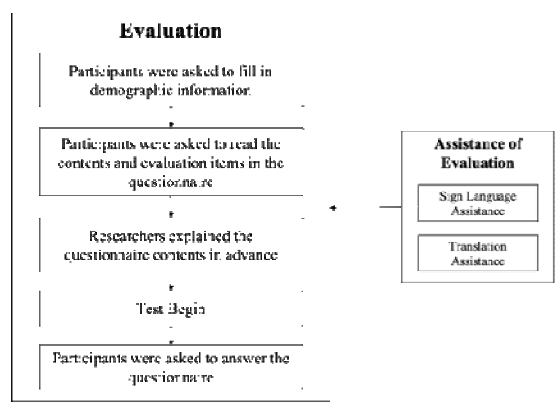


Figure 3. Evaluation test.

Measurements

According to the problem investigation results of the participants, the UD evaluation indices that reflect the problems identified by the participants regarding the transportation environment were divided into 15 types: (1) discoverability; (2) equity; (3) flexibility; (4) operability; (5) informativeness; (6) error tolerance and safety; (7) labor efficiency; (8) reassurance; (9) reasonable planning; (10) maintenance status; (11) comfortability; (12) aesthetics; (13) durability; (14) economy; and (15) environmental friendliness and energy efficiency. In particular, "discoverability" and "maintenance status" were additional indices implemented in this study for the consideration of transportation environment; furthermore, "durability," "economy," and "environmental friendliness and energy efficiency" require the professional knowledge of design or facility management for evaluation accuracy and were only answered by the managers and experts (Afacan & Erbug, 2009).

The facilities were evaluated using a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree) (Kumiko et al., 2006; Misugi et al., 2003; Nakagawa, 2006). The results corresponding to the UD characteristics were consolidated and displayed in a radar chart for easy analysis of the degrees of UD achievement, providing a reference for further improvement design.

Table 4. Universal design evaluation scale and items for the sign system

Task	Index	Item	Description
Searching for the signs	Discoverability	1-1	No obstacles interfered when you were finding the signs.
		1-2	The signs' locations did not overlap with each other.
Viewing the signs	Equity	2-1	The signs were easy for you to understand.
		2-2	To you, the signs are easy for others to understand.
	Flexibility	3	You could accurately comprehend the signs' information in a stressful situation (e.g., rush hour and crowds).
	Operability	4	You find the information on the signs easy to read.
	Informativeness	5-1	You find the information on the signs sufficient.
		5-2	You find the information on the signs at the major exits, intersections, and facilities clearly conveyed.
		5-3	You find the sign's information accurate.
		5-4	You find the signs' information continuous.
		5-5	There is no excessive information that could confuse people.
		5-6	You find the signs' images and text clear and easy to recognize.
		5-7	You find the signs' colors consistently arranged.
		5-8	You find the signs' text fonts consistently arranged.
		5-9	You find the terms used on the signs consistent.
		5-10	You find the language on the signs easy to understand.
		5-11	You find the lighting sufficient.
	Error tolerance	6	Even if one sign is confusing, you can find the next sign or

and safety		desired facility using the signs nearby.
Labor efficiency	7	You are able to view the signs with ease.
Safety	8	The information on the signs enable you to find your destination, and you trust the signs.
Reasonable planning	9-1	You find the locations of the signs eye-catching.
	9-2	You find the heights of the signs appropriate for viewing.
	9-3	You find the locations of the signs well-coordinated with the surrounding space.
Maintenance status	10	You find the signs clean and without damage.
Comfortability	11	You find the signs' information arrangement orderly and clear.
Aesthetics	12	You find the shapes and colors of the sign's aesthetic.

Results

UD Evaluation Results for the Existing and New Sign Systems

This subsection discusses whether the two sign systems and the app fulfilled the UD principles. The transportation environment was evaluated for its fulfillment of UD indices using the 5-point Likert scale; the results were displayed in a radar chart to illustrate the environment's UD characteristics. A score of 4 indicated that the evaluator agreed that the facility satisfied UD. Accordingly, a preliminary assessment was performed using the radar chart, and an analysis with further accuracy was run through a one-sample t test with the certified value of 4.

According to the radar chart, the existing sign system scored below the certified values on all the scale items, revealing several conditions that required the utmost improvement.
The new sign system scored close to the certified values on all the scale items, indicating that it nearly satisfied the improvement goal for UD even though improvements over the preliminary plan were still desired. The new system, when incorporated with the navigation app, scored higher than the certified values on all the scale items; this indicated that the improved system, when applied in conjunction with the auxiliary navigation app, satisfies UD.

Evaluation Results of the Existing and New Sign Systems by Pedestrians

According to the radar charts on the existing and new systems, the scores of the new systems in each item were significantly higher than those of the existing system, particularly in flexibility, reassurance, aesthetics, error tolerance, and safety. The participants were especially satisfied with the error tolerance, safety, and reassurance in the new systems. However, some of the participants indicated that the excessively bright background color of the column lightboxes in the new systems is dazzling, and furthermore, the color brightness of the area maps was too low; these concerns were reflected in the indicators of flexibility and aesthetics. Nevertheless, the brightly colored lines adopted in the

Figure 4. Universal design evaluation results of the existing and new sign systems.

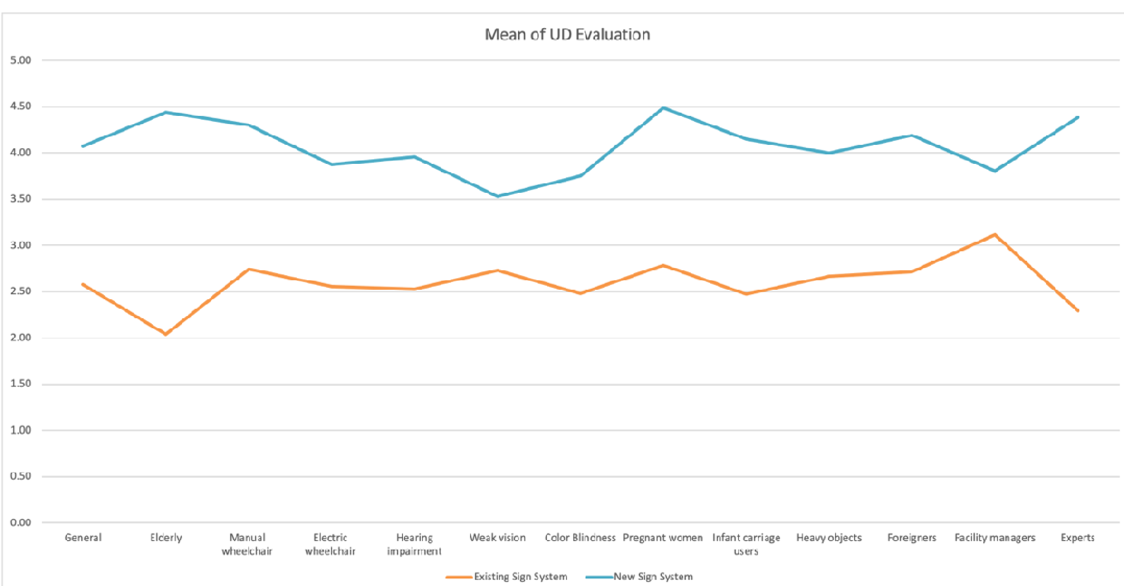


Figure 4 The Evaluation Results of Different Pedestrian Groups

new systems enable accurate navigation for users in the station environment.

Discussion

Improving the Design of the Sign System

Continual improvement is the basic principle of UD. According to the UD evaluation results, improvement plans are continually formulated for the sign systems and navigation app, providing a comprehensive practical example of UD design. Furthermore, continual improvements are made to the details in the system and app after the opinions of the participants are consolidated.

The average UD evaluation score of the existing system was 2.5957, and the system's test statistics were as follows: $t(38) = -15.643$, $p = 0.000$ (< 0.05). This indicated a significant difference between the evaluation results of the system and the certified values. According to the average score, all the scores in the existing system were significantly lower than 4, which was required to fulfill the "agree" criteria. Regarding the evaluation result for each item, the scores for all 12 indices were lower than 3 except for that of the "maintenance status." Accordingly, all these items require urgent improvement. In particular, item 3 of flexibility and item 5-5 of informativeness scored < 2, fulfilling the definition of "missing information" and "lack of integration in the sign information." The disorganized sign information has confused passengers, intensifying the difficultly of acquiring navigation information. Accordingly, the existing sign system must be improved according to various wayfinding conditions, and information integration must also be improved.

The average UD evaluation score of the new system was 4.0373, and the system's test statistics were as follows: $t(33) = 0.453$, $p = 0.653$ (> 0.05). No significant differences were identified between the evaluation results of the system and the certified values; according to the evaluators' responses, the new system satisfies UD overall, and thus fulfills the improvement goal expected in this study. Regarding the 12 UD indices and their individual items, the scores for equity, informativeness, error tolerance, safety, reasonable planning, and maintenance status were all > 4, indicating that the adjustment of the signs' installation location and the integration of their design specification were considerably effective. However, scores for item 2-2 of equity and item 5-5 of informativeness were significantly lower than 4. According to the feedback from participants, the functional types and layout design of the signs in the new system are diverse. Although these signs provide sufficient navigation information, the participants were required to spend additional time understanding their information contents. Accordingly, the equity and informativeness of the sign information display must be continually improved to fulfill the UD of sign systems.

The average UD evaluation score of the new system when jointly applied with the navigation app was 4.1888, and the system's test statistics were as follows: $t(21) = 0.453$, $p = 0.1010$ (> 0.05). Accordingly, the new system combined with the navigation app fulfilled UD

Table 5. One-sample *t* test results of the sign systems.

	Exist Sign System N=39			New Sign System N=34			New Sign System with Navigation App N=22		
	M	MD	t	M	MD	t	M	MD	t
1	2.54	-1.46	-9.05***	3.84	-0.16	-1.09	4.23	0.23	1.60
1-1	2.77	-1.23	-6.17***	3.82	-0.18	-0.95	4.45	0.45	3.58**
1-2	2.31	-1.69	-8.39***	3.85	-0.15	-0.93	4.00	0.00	0.00
2	2.46	-1.54	-12.43***	3.87	-0.13	-1.12	4.16	0.16	1.10
2-1	2.59	-1.41	-10.01***	4.18	0.18	1.44	4.36	0.36	2.94**
2-2	2.33	-1.67	-12.42***	3.56	-0.44	-2.88**	3.95	-0.05	-0.24
3	1.95	-2.05	-13.56***	3.71	-0.29	-1.83	4.05	0.05	0.33
4	2.64	-1.36	-8.17***	4.03	0.03	0.22	4.27	0.27	1.82
5	2.63	-1.37	-13.63***	4.07	0.07	0.77	4.17	0.17	1.49
5-1	2.77	-1.23	-7.23***	4.15	0.15	0.90	4.00	0.00	0.00
5-2	2.10	-1.90	-12.24***	4.09	0.09	0.50	4.32	0.32	2.08*
5-3	2.21	-1.79	-11.79***	3.91	-0.09	-0.72	4.14	0.14	0.90
5-4	2.67	-1.33	-9.27***	4.00	0.00	0.00	4.05	0.05	0.25
5-5	1.97	-2.03	-16.27***	3.35	-0.65	-3.20**	3.91	-0.09	-0.38
5-6	2.44	-1.56	-10.39***	3.68	-0.32	-1.77	4.27	0.27	1.45
5-7	2.62	-1.38	-7.76***	4.03	0.03	0.20	4.14	0.14	0.68
5-8	2.67	-1.33	-7.07***	4.18	0.18	1.29	4.41	0.41	3.25**
5-9	3.13	-0.87	-4.93***	4.47	0.47	5.42***	4.23	0.23	1.16
5-10	3.13	-0.87	-5.57***	4.50	0.50	5.17***	4.32	0.32	2.31*
5-11	3.23	-0.77	-5.71***	4.38	0.38	4.04***	4.05	0.05	0.30
6	2.79	-1.21	-8.42***	4.32	0.32	2.96**	4.18	0.18	1.00
7	2.54	-1.46	-9.99***	3.94	-0.06	-0.39	4.18	0.18	1.00
8	2.38	-1.62	-11.92***	4.32	0.32	2.59*	4.27	0.27	1.67
9	2.72	-1.28	-10.88***	4.07	0.07	0.68	4.11	0.11	0.72
9-1	2.59	-1.41	-9.39***	4.09	0.09	0.57	4.00	0.00	0.00
9-2	2.95	-1.05	-6.25***	3.97	-0.03	-0.21	4.05	0.05	0.24
9-3	2.62	-1.38	-8.74***	4.15	0.15	1.09	4.27	0.27	2.32*
10	3.13	-0.87	-4.64***	4.26	0.26	2.72*	4.59	0.59	4.70***
11	2.56	-1.44	-9.27***	4.09	0.09	0.59	4.23	0.23	1.31
12	2.41	-1.59	-11.28***	3.94	-0.06	-0.40	4.23	0.23	1.31
Avg	2.60	-1.40	-15.64***	4.04	0.04	0.45	4.19	0.19	1.72

Note: *p<0.05, **p<0.01, *** P<0.001

Table 6. One-way analysis of variance results of the sign systems.

	Sign System					Post Hoc Test		
	Total N=95	Type (1) N=39	Type (2) N=34	Type (3) N=22	F	MD (1)-(2)	MD (1)-(3)	MD (2)-(3)
1	3.39	2.54	3.84	4.23	31.88***	-1.30*	-1.69*	-
1.1	3.54	2.77	3.82	4.45	22.78***	-1.05*	-1.69*	0.63*
1.2	3.25	2.31	3.85	4.00	26.11***	-1.55*	-1.69*	-
2	3.36	2.46	3.87	4.16	51.99***	-1.41*	-1.70*	-
2.1	3.57	2.59	4.18	4.36	54.92***	-1.59*	-1.77*	-
2.2	3.15	2.33	3.56	3.95	30.18***	-1.23*	-1.62*	-
3	3.06	1.95	3.71	4.05	53.55***	-1.76*	-2.10*	-
4	3.52	2.64	4.03	4.27	36.14***	-1.39*	-1.63*	-
5	3.50	2.63	4.07	4.17	79.58***	-1.44*	-1.54*	-
5.1	3.55	2.77	4.15	4.00	19.92***	-1.38*	-1.23*	-
5.2	3.33	2.10	4.09	4.32	56.60***	-1.99*	-2.22*	-
5.3	3.26	2.21	3.91	4.14	55.73***	-1.71*	-1.93*	-
5.4	3.46	2.67	4.00	4.05	27.75***	-1.33*	-1.38*	-
5.5	2.92	1.97	3.35	3.91	28.64***	-1.38*	-1.93*	-
5.6	3.31	2.44	3.68	4.27	28.82***	-1.24*	-1.84*	-
5.7	3.47	2.62	4.03	4.14	25.75***	-1.41*	-1.52*	-
5.8	3.61	2.67	4.18	4.41	39.98***	-1.51*	-1.74*	-
5.9	3.86	3.13	4.47	4.23	23.76***	-1.34*	-1.10*	-
5.10	3.89	3.13	4.50	4.32	32.51***	-1.37*	-1.19*	-
5.11	3.83	3.23	4.38	4.05	24.39***	-1.15*	-0.81*	-
6	3.66	2.79	4.32	4.18	39.05***	-1.53*	-1.39*	-
7	3.42	2.54	3.94	4.18	33.03***	-1.40*	-1.64*	-
8	3.52	2.38	4.32	4.27	68.3***	-1.94*	-1.89*	-
9	3.52	2.72	4.07	4.11	47.04***	-1.35*	-1.39*	-
9.1	3.45	2.59	4.09	4.00	29.05***	-1.50*	-1.41*	-
9.2	3.57	2.95	3.97	4.05	14.33***	-1.02*	-1.10*	-
9.3	3.55	2.62	4.15	4.27	47.88***	-1.53*	-1.66*	-
10	3.87	3.13	4.26	4.59	29.68***	-1.14*	-1.46*	-
11	3.49	2.56	4.09	4.23	35.69***	-1.52*	-1.66*	-
12	3.38	2.41	3.94	4.23	43.26***	-1.53*	-1.82*	-

(1) = Exist Sign System, (2) = New Sign System, (3) = New Sign System with Guide App

*p<0.05, **p<0.01, *** P<0.001

overall. On the 12 UD indices and their individual items, scores for item 2-2 on flexibility and item 5-5 on informativeness were slightly lower than 4 (3.95 and 3.91, respectively) because the participants differ in their app usage habits. However, all the other items scored > 4, indicating that overall the participants agreed that the design of the new system satisfies UD. The scores of all the items on discoverability, equity, flexibility, informativeness, and maintenance status were higher than the certified values. This revealed that the auxiliary navigation app can be coordinated with the improved sign system to enable users from different groups to acquire navigation information, thereby substantially improving the friendliness and convenience of the transportation environment.

Suggestions for the Sign System Design Specifications

This subsection presents the finalized specifications according to the revisions on the language, symbols, text sizes, and layouts of the sign information, providing a basis for the layout design of sign systems in various facilities.

Language.

The character 臺 in 臺鐵 (Taiwan Railways) should be simplified to 台 for simple strokes and easy visual recognition. Currently, the HSR, TRA, and MRT Bannan Line are the only railway services in the station. Navigation to the Bannan Line should be provided without affecting the limited layout space in the station signs. In stations with multiple MRT lines, the names of specific lines should be specified to prevent confusion and information complexity within each sign. Furthermore, “Banqiao” should be removed from the text title “Banqiao Bus Station” for conciseness.

Symbols and Texts.

The side tips of the arrows should be parallel to the arrow directions to strengthen the arrows’ directionality and ease of recognition, thereby reducing the perception of arrow size inconsistency caused by direction differences. (Figure 5)

Color specification.

The background colors of the sign system suggest be redesigned to coordinate with the spatial color scheme of the station (

Table 7). For example, that of the overhead lightboxes was changed from black, which contrasted excessively with the spatial colors, to brighter brown, and those of the column and wall lightboxes were changed to beige.

Figure 5. Revised specifications of symbols, texts, and arrows

Table 7. Revised sign system color specifications

Color	Purpose
RGB (59,50,51)	Deep brown is adopted as the background color of the overhead light-boxes.
RGB (218,212,206)	Beige is adopted as the background color of the column and wall light-boxes.
RGB (255,255,0)	Yellow indicates the exit information.
RGB (255,255,255)	White indicates the entrance information.
RGB (31,42,102)	Color for the symbols.
RGB (201,54,100)	Peach is used as the base line color of the east–west direction signs for continuity with the colors of the artworks installed in the east–west passageway.
RGB (30,133,154)	Cyan is used as the base line color of the north–south direction signs; in addition, with its similarity to the color of the Bannan Line, it is used to indicate the route to the Bannan Line.

Conclusion

Through a sign system improvement plan for the main pedestrian passageways in Banqiao Station, this study established a practical case of UD to reinforce the feasibility of the UD procedure and method for business managers to promote and implement in accordance with their developmental procedures.

Consideration in the implementation of universal design.

Both the UD procedure and general product design procedure involve analytical, integration, and evaluation phases. Nevertheless, differences exist between the UD and general product design procedures. Because a broad scope of users must be considered in UD, users' needs must be taken into consideration in the analytical and integration phases to the maximum extent possible; therefore, the phases differ significantly from those of the general product design procedure, which concerns only a specific user group. The evaluation phase in the UD procedure emphasizes feedback; users, facility managers, and experts from different disciplines participate in each phase to ensure the systematic requirements and continuity of UD, thereby formulating the optimal design plan.

When implementing universal design, various user characteristics, user participation in the design process and orientation of transportation characteristics Consider the following aspects.

(a) Understanding users from different aspects

(b) Users participate in the initial stage of design

(c) Experts from different fields should participate in the design process

(d) Systematicity and continuity should be considered

(e) Include universal design considerations from the time of planning

(f) Pursue innovative design

(g) Combining technology in universal design

Identify the Universal Design Elements in Stations

This study planned a new sign system according to the problems identified by users of different groups in using the existing sign system to find their desired facilities in Banqiao Station. This study follows 9 universal design elements in transportation environments when designing proposals in this study: (1) reasonable dimension and placement; (2) indicative shape; (3) material chosen with safety consideration; (4) sufficient indicative lighting; (5) real time dynamic display; (6) content of information display;\(7) integration with surrounding environment; (8) application of multiple perceptions information; (9) modulated design.

Furthermore, a navigation system incorporating a VR scenario was adopted for the sign system improvement evaluation test. Users from different groups evaluated the new systems to verify their effectiveness and whether they satisfied the principles of UD. This improvement plan and the specifications for the colors, fonts, text sizes, and layouts in the new sign systems can be applied in other stations to maximize the effectiveness of the navigation functions of station facilities. This will promote social and economic activities and form a basis for sustainable development.

This study follows 9 universal design elements in transportation environments when designing proposals in this study: (1) reasonable dimension and placement; (2) indicative shape; (3) material chosen with safety consideration; (4) sufficient indicative lighting; (5) real time dynamic display; (6) content of information display;\(7) integration with surrounding environment; (8) application of multiple perceptions information; (9) modulated design.

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